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UNITED STATES
DEPARTMENT OF AGRICULTURE
DEPARTMENT CIRCULAR No. 380

Washington, D. C.

Issued April, 1926

CALCIUM CYANIDE AS A FUMIGANT FOR ORNAMENTAL GREENHOUSE PLANTS

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During the last few years the chemical compound known as calcium cyanide has attracted considerable attention from entomologists because of its promising insecticidal properties. More recently it has assumed a unique place in greenhouse insect warfare as a convenient source of hydrocyanic-acid gas for fumigating purposes. It is now available on the market in the form of dust and coarse and fine granules. These seem well adapted for greenhouse use; the dust is more finely ground and gives off the gas more rapidly than does the granular form.

Unlike fumigation with potassium or sodium cyanide by the "pot method," the use of calcium cyanide does not require jars or the addition of sulphuric acid and water to generate the gas. On exposure to the air, calcium cyanide slowly reacts with the moisture of the atmosphere and gives off hydrocyanic-acid gas. With the quantity commonly used this reaction continues for several hours. Gas generated by the pot method is given off almost instantly and reaches its maximum concentration within a very few minutes, and the fumigation normally requires only one hour's exposure. Calcium cyanide, on the other hand, because of its gradual liberation of the gas, gives a lower concentration, requiring exposures lasting from three hours to over night.

Hydrocyanic-acid gas, whether produced from calcium, sodium, or potassium cyanide, is a cheap and effective insecticide, useful for controlling aphids, thrips, white flies, and other insects occurring on plants grown under glass. It should be remembered, however, that

this gas is very poisonous and that unless it is handled with proper caution its use may cause disastrous results to the plants and the operator. Hydrocyanic-acid gas is colorless and has the odor of peach pits.

PREPARATION OF GREENHOUSE FOR FUMIGATION

Before attempting to fumigate, it is essential that the greenhouse be made as nearly gas tight as possible by replacing broken glass and closing tightly all ventilators, doors, or other openings that are not to be used during the exposure. At times it may be necessary to fumigate on hot nights in the summer months, or to employ a dosage heavier than usual, as in the control of scale insects on orchids, palms, rubber plants, aspidistra, and other plants which can tolerate a higher concentration of gas; in either case it may not be desirable to run the exposure throughout the night.

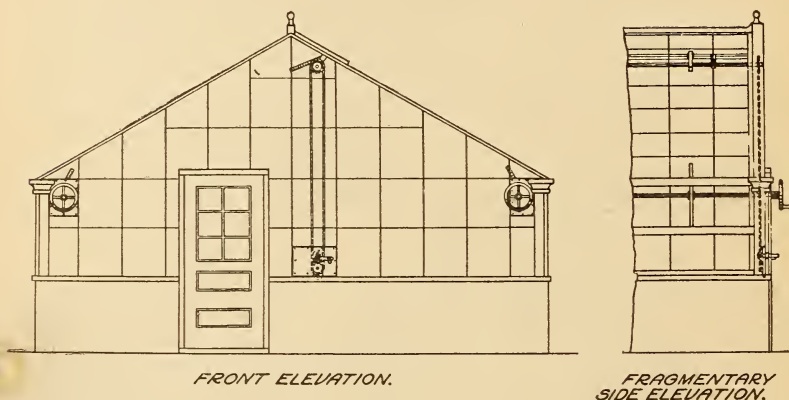


FIG. 1.—Arrangement for opening roof and side ventilators from outside the end of the greenhouse

Because of the high concentration used under these conditions, it is safer not to enter the greenhouse until it has been ventilated. To avoid possible danger, a greenhouse can be aired at the end of the fumigation by having the side and roof ventilators arranged so that they can be operated from the outside. There are various ways in which this can be accomplished. A method recently devised by the writer and used successfully in the greenhouses of the United States Botanic Garden is to disconnect the gears by which the ventilators are operated from within and attach extensions to the main shafts of the roof and side ventilators, so that they project through the end of the greenhouse. The control wheel for each side ventilator is then attached to its extension. In case of the roof ventilator a spare control may be installed on the outside of the greenhouse, at the end, as shown in Figure 1. For greenhouses several hundred feet long alternate sections of the ventilators may be disconnected and operated from the sides of the house by removing the local control and attaching to the gear a piece of gas piping or half-inch round iron shafting. This shafting should extend through the side of the house and have the

control wheel attached to its free end (fig. 2). In a method devised by Sasscer and Borden an arm (*a* or *b*, fig. 3) is attached to the central ventilator shaft, after disconnecting the operating gear of the roof ventilators. This arm can be controlled by a cord or wire which extends through the side of the greenhouse (fig. 4.) If only

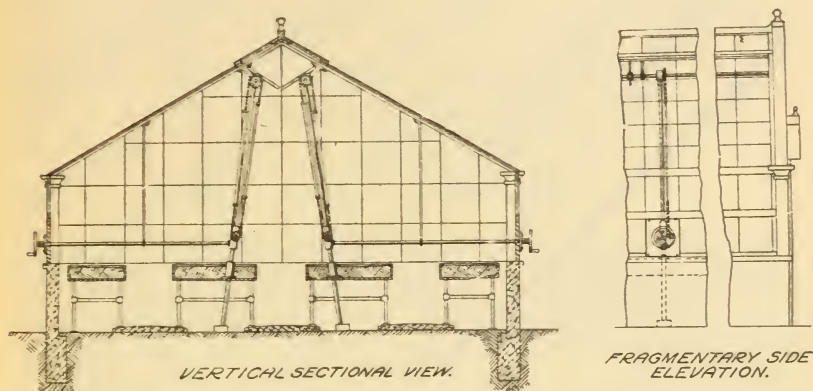


FIG. 2.—Arrangement for opening roof ventilator from without, on sides of the greenhouse

one ventilator can be opened, it is preferable that it be the one on the roof of the greenhouse. This method may be modified by extending the main shaft through one end of the greenhouse, as previously explained, and attaching to its free end an elbow connection, making with it a right angle and bearing a pipe extension several feet long. After disconnecting the controls, the ventilators can be operated from the outside by raising the pipe extension enough to lift the ventila-

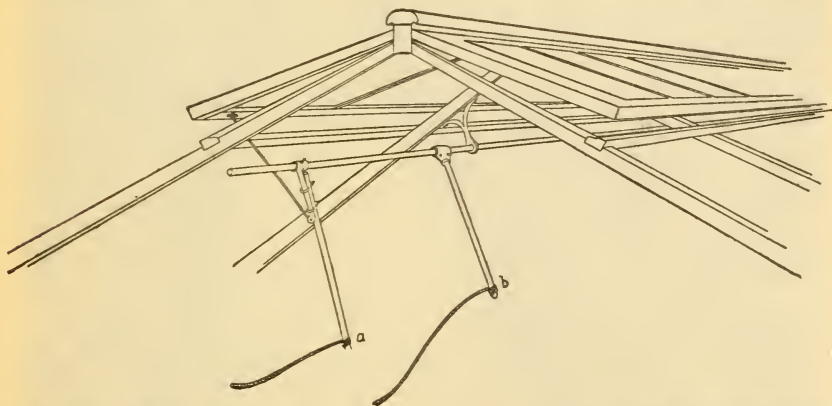


FIG. 3.—Methods of attaching rod and cord (*a*, *b*) to ventilator shaft of a greenhouse so that the ventilator can be opened from the outside after fumigation (Sasscer and Borden)

tors a few inches. A piece of wooden studding placed on end may be used to support the pipe extension while the ventilators are raised.

The gears on the side ventilators may be disconnected so that the sashes may be opened by merely lifting them from the outside, and propped with any convenient support until the ventilation is complete.

USE OF CURTAINS TO SEPARATE PORTIONS OF A RANGE

In the open-range type of greenhouses where miscellaneous crops are grown, it is not always necessary or desirable to fumigate the the



FIG. 4.—Interior of greenhouse. Arrangement of ventilator arm and attached cord, to enable operation from the outside

whole series of houses at one time or with the same dosage. For example, when a particular insect is localized on one crop it may be unnecessary to fumigate the whole range, or it may be undesirable to do so when plants growing in the adjoining sections are likely to

be injured by the dosage used. In such cases the house or portion to be fumigated may be separated from the others by the use of canvas or muslin curtains (fig. 5). These may be cut in 50-foot lengths to permit easier handling. The width should be such that the curtains when hung will make a partition from the roof to the ground. The same object may be attained by constructing a temporary partition of sash, resting on the ground and nailed to the eaves plate, or by using oiled or tarred paper fastened to upright wooden supports. When either of these devices is employed in mild weather the ventilators in the adjoining portions may be left open, or raised so far that any gas coming from the fumigated houses will soon escape. In extremely cold weather, of course, this can not be done, because the plants might be chilled if the ventilators were left open.

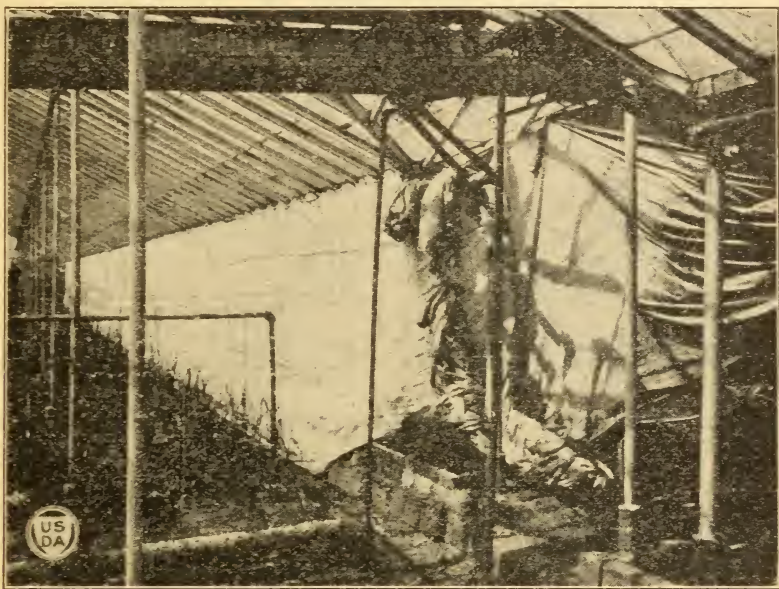


FIG. 5.—Muslin curtains used to separate sections of an open range of greenhouses during fumigation. (Weigel and Doucette)

HOW TO DETERMINE THE CUBICAL CONTENTS OF A GREENHOUSE

In estimating the cubical contents of a greenhouse, it is not necessary to deduct the space occupied by the benches and pots.

To determine the cubical contents of a greenhouse of rectangular ground plan, as nearly all greenhouses are, first find the area of the end of the house and multiply it by the length. If all the dimensions used are expressed in feet, the result will be the volume in cubic feet. Upon the shape of the end of the greenhouse depends the method of computing its area. Almost without exception the end of a greenhouse has a horizontal base and vertical sides. The height of each side and the height of the ridge above the floor are dimensions which must be known. In addition, if the sides are of the same height, that is, if the greenhouse is of the "even-span" type, the width of the house should be multiplied by the average height, or half the sum of the height of one side and the height of the ridge. If the sides are

unequal, it will be necessary to find the horizontal distance from the foot of each side to the foot of a vertical line through the ridge, dividing the end into two parts. The area of each part can be found by multiplying its width by its average height, or half the sum of its two vertical sides, one of the two being always the height of the ridge.

For example, in the case of an even-span greenhouse 20 feet wide, 5 feet high at the eaves, 10 feet high at the ridge and 100 feet long (fig. 6), we have for the area of the end $\frac{10+5}{2} \times 20 = 150$ square feet; and for the cubical contents, $150 \times 100 = 15,000$ cubic feet.

To determine the cubical contents of a greenhouse having unequal sides, a three-quarter span greenhouse 24 feet wide, 100 feet long, and 12 feet high (fig. 7) will serve as a good example. Here the end of the house is divided into two areas, one (a) having a base 6 feet long and sides 12 feet and 8 feet high, and the other (b) a base

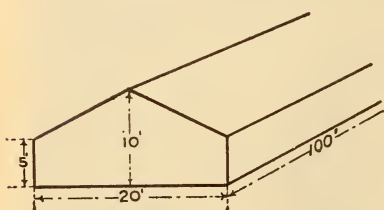


FIG. 6.—Diagram illustrating method of computing cubical contents of an even-span greenhouse

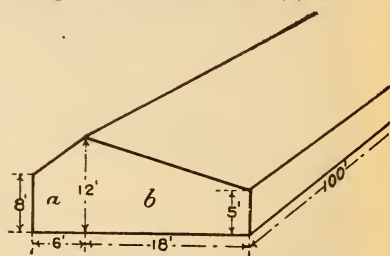


FIG. 7.—Diagram illustrating method of computing cubical contents of three-quarter, or other uneven, span greenhouse

18 feet long and sides 12 feet and 5 feet high. For the first area we have

$$\frac{12+8}{2} \times 6 = 60 \text{ square feet,}$$

and for the second,

$$\frac{12+5}{2} \times 18 = 153 \text{ square feet.}$$

For the two areas we have a total of 213 square feet. Multiplying 213 by 100, the length of the greenhouse, we find that it contains 21,300 cubic feet.

QUANTITY OF CALCIUM CYANIDE TO USE

In cyanide fumigation it is convenient to state the dosage or rate in terms of ounces of calcium cyanide for each 1,000 cubic feet of air space in the house. At the quarter-ounce rate the even-span greenhouse (fig. 6) having a capacity of 15,000 cubic feet would require 15 quarter ounces or $3\frac{3}{4}$ ounces of calcium cyanide. The three-quarter-span house (fig. 7) with a capacity of 21,300 cubic feet would require 21 quarter ounces or $5\frac{1}{4}$ ounces of calcium cyanide. The correct dosage for a particular purpose depends on the tightness of the house, the kind of insect to be controlled, and the susceptibility of the plants to injury.

In a relatively air-tight house an overnight fumigation at the quarter-ounce rate is effective in controlling adult white flies and

the various species of aphids (see Table 1) which attack roses, carnations, chrysanthemums, and similar floral crops, with little or no injury to the plants. Should this dosage prove ineffective, because the house is too leaky to retain a sufficient concentration of the gas the rate can be gradually increased in succeeding fumigations to one-third ounce or one-half ounce, or until a dosage rate is found which will control the insects without injuring the plants. In no case is fumigation at rates in excess of 1 ounce recommended unless the florist first tries it out on a small scale under his particular conditions.

TABLE 1.—Percentage mortality of various greenhouse insects obtained by the use of calcium cyanide granules at the rates indicated

Insect	Dosage per 1,000 cubic feet	Expo- sure	Temper- ature at begin- ning of exposure	Humid- ity at begin- ning of exposure	Number of speci- mens	Per cent of mortality
	Ounces	Hours	° F.	Per cent		
Greenhouse whitefly (adults), <i>Trialeurodes vaporariorum</i> Westw.	$\frac{1}{4}$	14	59	83	135	100
Thrips (adults)	1	10	69	90	65	85
Greenhouse leaf tyer (moths), <i>Phlyctena rubigalis</i> Guen.	$\frac{1}{2}$	4	65	65	32	100
Aphids:						
Brown chrysanthemum aphid, <i>Macrosiphoniella sanborni</i> Gill	$\frac{1}{4}$	12	72	86	1,126	100
Green chrysanthemum aphid, <i>Rhopalosiphum rufomaculata</i> Wils.	$\frac{1}{4}$	13	53	76	1,150	100
Peach aphid on carnation, <i>Myzus persicae</i> Sulz.	$\frac{1}{4}$	13	63	84	880	63
Rose aphid:						
<i>Macrosiphum</i> sp.	$\frac{1}{4}$	12	72	86	634	100
<i>Myzaphis</i> sp.	$\frac{1}{4}$	12	66	90	3,000	100
Nasturtium or bean aphid, <i>Aphis rumicis</i> Linn.	$\frac{1}{4}$	15	69	67	193	100
Sweet pea aphid, <i>Illinoia pisi</i> Kalt.	$\frac{1}{4}$	13	53	76	238	98.7
Anuraphis helichrysi	$\frac{1}{4}$	1	61	89	264	65.1
Mealybugs:						
Citrus mealybug, <i>Pseudococcus citri</i>	$\frac{1}{8}$	15	71	52	118	196.4
Risso	$\frac{5}{8}$	13	72	55	199	93.9
Palm mealybug, <i>Pseudococcus nipae</i>	$\frac{1}{8}$	15	68	42	413	97.3
Mask	$\frac{3}{4}$	15	70	59	158	96.2
Baker's mealybug, <i>Pseudococcus maritimus</i> Ehrh.	$\frac{1}{2}$	4	65	65	70	0
Greenhouse orthezia, <i>Orthezia insignis</i> Dougl.	$\frac{1}{2}$	12	73	85	25	100
Azalea bark scale, <i>Eriococcus azaleae</i>	3	13	70	64	326	79.7
Comst.	3	16	64	38	70	100
Scale insects:						
Florida red scale, <i>Chrysomphalus aonidum</i> Linn.	$\frac{1}{2}$	15	68	42	90	97.8
Morgan's scale, <i>Chrysomphalus dictyospermi</i> Morg.	$\frac{3}{4}$	15	70	59	355	100
Orchid scale, <i>Chrysomphalus biformis</i> Ckll.	$\frac{1}{2}$	6	70	64	570	100
Boisduval's scale, <i>Diaspis boisduvalii</i> Sign.	4	14	61	49	176	100
Proteus scale, <i>Parlatoria proteus</i> Curt.	1	12	66	85	650	100
Hemispherical scale, <i>Saissetia hemisphaerica</i> Targ.	$\frac{1}{2}$	15	68	42	382	198.1
Purple scale, <i>Lepidosaphes beckii</i> Newm.	$\frac{3}{4}$	16	69	67	215	23.2
	$2\frac{1}{2}$	14	71	52	200	97.5

¹ Young.

² Adult.

Table 1¹ gives the dosage rates of calcium cyanide that have been found, in recent experiments, to kill some of the insect pests frequently encountered in greenhouses. Before fumigation is undertaken, however, Table 3 should be consulted to ascertain the rate or

¹ The data presented in the tables represent actual results of experimental tests under the conditions stated, and are not intended as definite recommendations. Differences in dosages and in length of exposure are intended to suggest the probable range of conditions under which a given fumigation might be expected to be safe or effective. For example, in the summer the duration of a fumigation may be restricted to from 3 to 10 hours, whereas in the winter months it might last from 10 to 15 hours.

dosage that particular plants can tolerate with little or no injury. If this dosage is less than that indicated in Table 1, of course, complete control can not be expected with one fumigation, as the adults, which are more resistant, will survive and continue to produce young. It will therefore be necessary to repeat the fumigation at frequent intervals until the infestation is eradicated.

HOW TO APPLY CALCIUM CYANIDE

After determining how much calcium cyanide is necessary, weigh out the required quantity and place it in a wide-mouthed bottle or other container. Then scatter evenly on the surface of the center walk or path (fig. 8), beginning at the far end and, walking backward, working toward the door. A convenient container for scattering calcium cyanide may be made from a baking-powder can by puncturing holes in the cover from the inside, using a 10-penny nail. A wide-mouthed glass jar with a perforated metal top can be used instead, and the glass jar enables the operator to watch the rate of distribution. Do not place the cyanide in the can or jar until ready to fumigate. Because calcium cyanide gives off gas when exposed to the air, the container in which it is stored should be kept tightly closed, and the quantity set apart for a given fumigation should be kept in a stoppered bottle or other secure container until about to be used. When spreading the material, be careful that none of it comes in contact with the plants. For larger greenhouses divide the material equally and scatter on two or more walks, depending on the width of the house. In such cases it is safer for one not to fumigate alone, but to have an operator for each path in which the calcium cyanide is to be applied.

Calcium cyanide must not be placed in piles, as is customary in fumigation with nicotine or tobacco, because the atmospheric moisture could not readily reach the inner portion of the pile, and probably not all the gas would be given off. Moreover, the gas evolved would not be evenly diffused throughout the greenhouse. With a little practice the operator soon learns how to scatter the material evenly from end to end of the greenhouse.

WHEN AND HOW OFTEN TO FUMIGATE

Greenhouse fumigation should be done only after dark and should not begin earlier than one hour after sunset. It should be done on still nights, because high winds may reduce the concentration by drawing the gas out of the greenhouse. Fumigation in the winter should preferably be done in mild weather and not on extremely cold nights, when it might be difficult to maintain proper temperatures. Hot, humid nights should also be avoided, because the temperatures can not be lowered to the required limit. Temperatures ranging between 60° and 70°F. are most desirable.

The frequency of fumigation depends on the kinds of insects to be controlled and the proportion killed with one exposure. If a trial fails to give satisfactory results, fumigation should be repeated. When greenhouses containing an assortment of plants were fumigated with sodium cyanide, small dosages were found necessary. Fumigation with such dosages killed only larvæ of scale insects, the adults and first larva stages of the greenhouse white fly, and most of the aphids. Moreover, the eggs and pupæ of most greenhouse insects

offer considerable resistance to hydrocyanic-acid gas and overlapping of broods frequently occurs. For these reasons several fumigations at intervals of a week or 10 days are often necessary in controlling such insects without injury to the plants. Data from experiments



FIG. 8.—Method of distributing calcium cyanide by means of a bottle with perforated cap

thus far conducted with calcium cyanide show that a satisfactory control of scale insects may be had by several fumigations at short intervals. Successive fumigations are very useful, even though no marked infestations exist, and are also a safeguard against sudden outbreaks.

Box fumigation may be done at any time, except that the plants must be shaded for at least a short time before and for a longer period after treatment. Immediate exposure to light, and particularly to bright sunlight, is very injurious to plants, especially palms and ferns, that have been fumigated in a box.

LENGTH OF EXPOSURE

Mention was made on page 1 of the gradual liberation of gas from calcium cyanide, which makes it well suited for long or overnight exposures. Recent experiments in a tight fumigation box with four species of aphids have confirmed this conclusion, as shown by the results presented in Table 2. It is evident that in all cases, even at the lowest dosage rates, exposures lasting overnight gave virtually complete control of the aphids. The relatively low control resulting from an exposure of one hour to various dosage rates up to three-fourths of an ounce of calcium cyanide indicates that one hour is too short a time to permit an effective concentration of the gas. In other experiments,² not presented in this article, very finely ground calcium cyanide gave a mortality of 82.7 per cent of the green chrysanthemum aphid (*Rhopalosiphum rufomaculata*) with an exposure of only one hour. In these experiments it became evident that calcium cyanide dust gives off the gas more rapidly than the granules, and that certain species of aphids are more susceptible to the gas than others. Beginning with a minimum dosage of one-half ounce and exposures lasting three hours or longer, a satisfactory control was obtained. Such results can, of course, be obtained only in cases where the greenhouses and fumigation boxes are tight enough to retain an effective concentration of the gas during the fumigation.

TABLE 2.—Degree of control of four species of aphids which resulted from box fumigation with calcium cyanide, with varying dosages and exposures

Dosage per 1,000 cubic feet	Exposure	Temperature	Humidity	Mortality of—			
				Nasturtium aphid ¹	Rose aphid ²	Black chrysanthemum aphid ³	Green chrysanthemum aphid ⁴
Ounces	Hours	° F.	Per cent	Per cent	Per cent	Per cent	Per cent
1/16-----	16	69	59	99.6	99	100	100
1/8-----	15	72	49	99.6	100	100	100
1/4-----	1	60	78	5	15.3	10.8	2.5
1/4-----	6	66	66	9	20.7	56.2	78.2
1/4-----	15	67	58	98.5	94.9	100	100
1/4-----	15	71	52	100	100	100	100
1/2-----	1	69	67	24.3	13.5	19.1	17.8
1/2-----	3	69	81	52.1	41.4	79	85
1/2-----	6	62	64	73.6	80	91.5	85.3
1/2-----	15	63	69	100	100	100	100
3/4-----	1	68	58	52.4	69.2	71.7	77.7
3/4-----	15	78	53	100	100	100	100

¹ *Aphis rumicis* L.

² *Myzaphis* sp.

³ *Macrosiphoniella sanborni* Gill.

⁴ *Rhopalosiphum rufomaculata* Wils.

The foregoing information is very important and useful when applied to the fumigation of crops where there is doubt as to the advisability of subjecting plants to a long exposure on hot nights, or where heavier dosages are employed, as in the case of orchids. Under such

conditions the ventilators may be raised or the fumigation box opened at the end of three hours and the house or box aired. The quantity of gas given off by any residual cyanide would after airing be negligible.

VENTILATION AFTER FUMIGATION

In fumigating with sodium cyanide short exposures, such as one or two hours, with a dosage ranging from one-half ounce to 1 ounce of the cyanide per 1,000 cubic feet, appeared to be more satisfactory than a lower strength of gas over night. The short exposures had the additional advantage of permitting the greenhouse to become thoroughly aired previous to the rising of the sun. Recent tests with calcium cyanide at such low dosages as one-fourth ounce made in large commercial houses in Washington, D. C., and in eastern Pennsylvania, have shown that ventilation is rarely necessary, except in new and exceptionally air-tight greenhouses, since little if any of the gas remains in the ordinary type of house after over-night fumigation. In any case, however, if the odor of gas is strong, the greenhouses should be thoroughly aired the following morning, before the sunlight strikes the plants.

BOX FUMIGATION

Florists and nurserymen will find it very advantageous to have a fumigation box for the following purposes: (1) In preliminary tests, to determine the quantity of gas that plants can withstand without injury in the several stages of growth; (2) to rid individual or potted plants of insects when an isolated infestation is discovered, and thus to avoid the frequently used costly and laborious hand scrubbing of the plants; (3) when it is unnecessary to fumigate an entire greenhouse. Its use is almost indispensable for such plants as orchids, palms, aspidistra, and ferns, and has an advantage in that it may be used in the daytime; whereas house fumigation can be performed with safety after dark only. Moreover, in box fumigation such factors as leakage, light, moisture, and temperature, which influence the success of the treatment, vary less than in greenhouses.

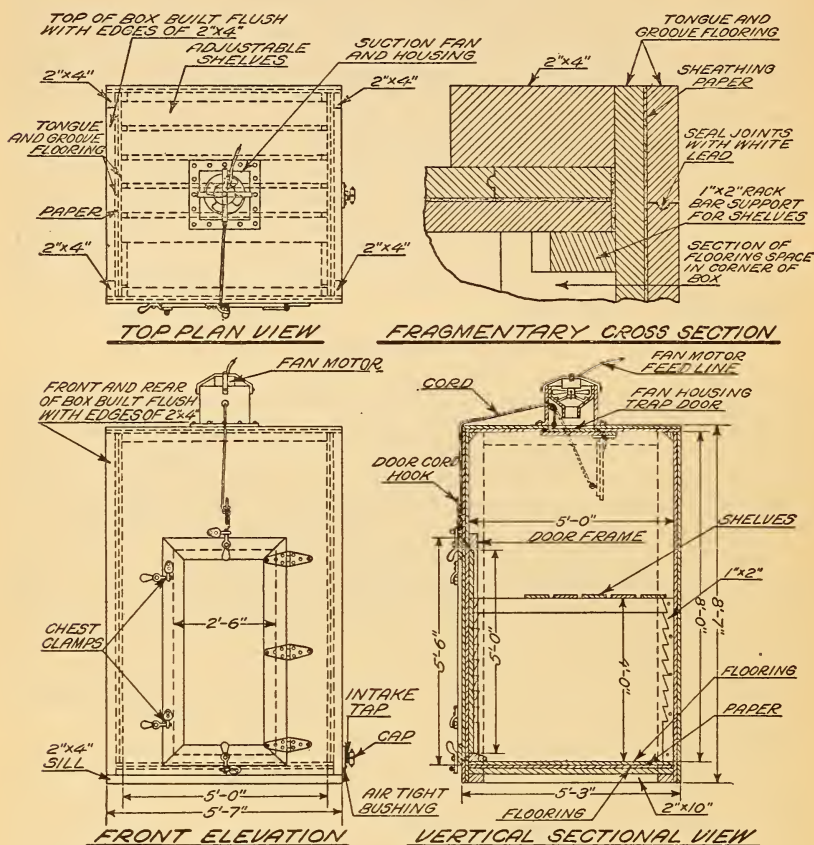
Plants to be fumigated in a box in the daytime should remain in the box with the door nearly closed, so as to prevent direct rays of light from reaching them for at least one hour before the gas is generated. After the completion of the exposure, plants should be shaded from bright sunlight for at least four hours. For shading, a closely constructed slat house or potting shed is suitable.

CONSTRUCTION OF A FUMIGATION BOX

The capacity of the box will naturally depend on the size of the establishment and the amount of fumigating to be done. Normally a box 5 feet square by 8 feet high, plans of which are given in Figure 9, is adequate for the average floral establishment.

For the framework use 2 by 4 inch material, and for the double walls, roof, and floor use 2-inch tongue-and-groove pine sheathing, or matched lumber, with heavy building paper or wall board between. The material of the inside walls should run horizontally and that of the outside walls vertically. The door should be built somewhat like that of a refrigerator and swing on three heavy hinges, the edges closing against a felt or rubber seat. Similar precautions should be

taken for the casings of the ventilator in the roof, in order to make it air-tight. If the volume of business warrants it, the walls may be made of concrete, or glazed hollow tile laid in cement. A series of adjustable shelves, as shown in the plans, upon which the plants can be placed, permits a better diffusion of the gas around the material to be fumigated. The suction fan referred to in the plans is not absolutely necessary, except when the box is built within a com-



BUILDER NOTE:-- ALL DOOR OPENINGS ARE TO BE FACED WITH FELT OR OTHER SUITABLE SEALING MATERIAL AND EVERY CRACK, JOINT OR THE LIKE, THAT MAY PERMIT THE ESCAPE OF FUMES FROM THE INTERIOR OF THE BOX, WHEN IN OPERATION MUST BE SEALED LIKEWISE.

FUMIGATION BOX

FIG. 9.—Plans of a 200-cubic-foot fumigation box, showing details of construction (Weigel and Sasseer)

mercial packing or shipping room in which many people may be working, or when time is a factor; in other cases the ordinary ventilator is a sufficient opening to permit the escape of the gas.

Fumigation boxes should not remain exposed to the weather, as they will soon warp and become unfit for use. For this reason it is advisable also to keep doors and ventilators closed when the box is not in operation.

EFFECTS OF WEATHER AND OTHER CONDITIONS ON FUMIGATION

Among the various factors which influence the effectiveness of calcium cyanide as a fumigant are temperature, humidity, moisture, light, and high winds.

Temperatures ranging from 60° to 70° F. are preferred, because the insects become inactive at low temperatures and are then more resistant to the gas, and if the temperature drops below 55° F. moisture may appear on the leaves, thus increasing the risk of injury to the plants. High temperatures should be avoided, because succulent tender growth under such conditions is particularly susceptible and is likely to be injured.

Humidity or atmospheric moisture is an essential factor in releasing the hydrocyanic-acid gas from the calcium cyanide. The results of the experiments made thus far indicate that relative humidities of from 40 to 70 per cent are sufficient for this purpose. Extremely high humidity, especially if accompanied by a temperature above 70° F., a condition that often exists on a muggy night, increases the risk of injury.

The presence of excessive moisture in the greenhouse reduces the concentration of the gas and is therefore undesirable. The plants should not be watered just prior to fumigation. The walks or paths may be damp, but no standing water should be present, as the gas, which is soluble in water, would be taken up by it. When the calcium cyanide is sprinkled on wet walks complex reactions take place which reduce the normal quantity of hydrocyanic-acid gas given off, thus impairing the effectiveness of the fumigation.

To avoid the decidedly injurious effect of sunlight on the fumigated plants, greenhouse fumigation should be attempted only after sunset and in the dark. The internal conditions and active growth of the plants during daylight or while exposed to sunlight renders them more susceptible to the effects of the gas. The breathing pores, or stomata, are also likely to permit the entrance of more gas into the tissues than they would absorb in the dark. Shading the plants, especially palms and ferns, from direct sunlight for a few hours after fumigation is of value in reducing the risk of injury and often prevents the occurrence of burning.

Still nights are preferable for fumigation, because high winds or strong currents of air tend to draw the gas out of any greenhouse which is not airtight and thus to prevent effective fumigation.

PRECAUTIONS

Do not guess at the cubical contents of the greenhouse or the quantity of cyanide to be used.

Fumigate greenhouses at night only. Box fumigation, however, may be done during the day.

Fumigate at temperatures above 55° F., preferably between 60 and 70° F.

Keep the cyanide away from people unacquainted with its poisonous nature and see that it is properly labeled. Avoid handling it more than necessary, and wash the hands after using.

Stay out of the greenhouse during fumigation. Tightly close the house and ventilators. Post warning signs before fumigating. Do not attempt to fumigate a large greenhouse alone.

If the greenhouse to be fumigated is near, or attached to, a dwelling the occupants should leave the house until the fumigation has been completed and thorough ventilation has rendered the premises safe.

GUIDE TO GREENHOUSE FUMIGATION

Table 3, which is offered as a guide to those desiring to employ calcium cyanide for controlling greenhouse insects, is based on the results of the experiments conducted thus far at the rates indicated. Temperature and humidity readings were made at the beginning of each fumigation test. As is evident in this table, certain plants are more susceptible than others to injury from hydrocyanic-acid gas. For example, such plants as *Asparagus plumosus* and *A. sprengeri*, Wandering Jew, snapdragon, sweet pea, chrysanthemum, marguerite, heliotrope, ageratum, and rose will not tolerate as high a concentration of gas as ferns, palms, rubber plants, orchids, and aspidistra. It is imperative that this fact be borne in mind when a greenhouse or range of houses containing a miscellaneous assortment of plants is to be fumigated.

In the case of most varieties of plants, it is the newest growth that may be damaged, particularly the young and tender tips and buds; the mature growth is less likely to show injury. Because of this fact, fumigating for the control of insects at a time when there is a minimum of succulent growth on the plants will materially reduce the risk of injury. Where the infestation is so heavy as to require the immediate treatment of plants which are easily burned, the florist must choose between the loss which would result from continued injury by insects and that caused by fumigation, the latter being usually only temporary and speedily outgrown.

TABLE 3.—Results of fumigation with calcium cyanide in greenhouses and fumigation boxes

[Plants designated by * were fumigated in a box]

Name of plant	Cyanide per 1,000 cubic feet of space	Length of exposure	Green- house temper- ature	Green- house hu- midity	Effect of treatment on plants
	Ounces	Hours	° F.	Per cent	
<i>Abelia grandiflora</i>	$\frac{3}{4}$	12	73	92	No burning.
<i>Abutilon eclipse</i>	$\frac{3}{4}$	12	73	92	Do.
<i>Acalypha godseffiana</i>	1	10	69	90	Do.
<i>Acalypha wilkesiana</i>	1	10	69	90	Do.
<i>Ageratum</i> sp.....	$\frac{1}{4}$	12	61	90	Do.
Do.....	$\frac{1}{2}$	14	74	61	Do.
<i>Ageratum dwarf</i>	$\frac{1}{2}$	12	73	93	Slight burning.
<i>Allamanda hendersoni</i>	$\frac{3}{4}$	12	73	92	Do.
<i>Alternanthera</i>	2	1	68	83	Do.
* <i>Amaryllis</i> (<i>Hippeastrum</i> sp.).....	$2\frac{1}{2}$	16	86	56	No burning.
<i>Anthericum liliago variegatum</i>	$\frac{1}{2}$	14	74	61	Do.
<i>Aralia sieboldi</i> (<i>Fatsia japonica</i>).....	$\frac{3}{4}$	12	73	92	Do.
* <i>Artillery plant</i> (<i>Pilea muscosa</i>).....	$\frac{1}{8}$	16	69	59	Moderate injury.
*Do.....	$\frac{1}{8}$	15	72	49	Severe injury.
<i>Asparagus plumosus</i>	$\frac{1}{4}$	13	63	84	Severe burning.
* <i>Asparagus sprengeri</i>	$\frac{1}{8}$	15	72	49	Trace burning on new tips.
<i>Aspidistra lurida</i>	1	15	69	63	No burning.
<i>Aspidistra lurida variegata</i>	1	15	69	63	Do.
<i>China aster</i> (<i>Callistephus</i>).....	1	10	69	90	Very slight.
* <i>Azalea indica</i>	$\frac{1}{2}$	6	63	71	No burning.
*Do.....	3	16	64	38	Slight spotting of tips.
<i>Banana</i> (<i>Musa</i>).....	$\frac{3}{4}$	12	73	92	No burning.
<i>Begonia</i> sp.....	$\frac{3}{4}$	12	73	92	Do.
<i>Begonia</i> sp.....	2	15	71	60	Do.
<i>Bleeding heart</i> (<i>Dicentra spectabilis</i>).....	1	10	69	90	Do.
<i>Blue lace flower</i> (<i>Trachymene caerulea</i>).....	$\frac{1}{4}$	1	61	89	Do.

TABLE 3.—Results of fumigation with calcium cyanide in greenhouses and fumigation boxes—Continued

Name of plant	Cyanide per 1,000 cubic feet of space	Length of exposure	Green- house temper- ature	Green- house hu- midity	Effect of treatment on plants
	Ounces	Hours	° F.	Per cent	
Blue sage (<i>Salvia azurea</i>).....	$\frac{3}{4}$	12	73	92	No burning.
Brugmansia (<i>Datura suaveolens</i>).....	2	1	68	83	Do.
Buddleia forresti.....	$\frac{3}{4}$	12	73	92	Severe injury.
Buddleia variabilis.....	$\frac{3}{4}$	12	73	92	Do.
Buxus sempervirens var. <i>suffruticosa</i>	$\frac{3}{4}$	12	73	92	No burning.
Calla (<i>Zantedeschia</i>).....	$\frac{1}{4}$	14	59	83	Do.
Camphor (<i>Cinnamomum camphora</i>).....	$\frac{1}{2}$	11	63	98+	Do.
Cape-jasmine (<i>Gardenia florida</i>).....	$\frac{1}{2}$	11	63	98+	Do.
Carnation (<i>Dianthus caryophyllus</i>).....	$\frac{1}{2}$	14	74	61	Do.
Caryopteris incana (blue spiraea).....	$\frac{1}{2}$	12	70	91	Do.
Cereus (night-blooming).....	$\frac{1}{2}$	11	63	98+	Do.
Chrysanthemum sp.....	$\frac{1}{4}$	10	61	90	Slight injury.
Do.....	$\frac{1}{4}$	13	54	76	No burning.
*Do.....	$\frac{1}{2}$	15	71	64	Severe injury.
Cissus discolor.....	$\frac{1}{2}$	12	73	93	No burning.
Coleus sp.....	$\frac{1}{2}$	11	63	98+	Severe injury.
Do.....	$\frac{1}{2}$	14	69	90	No burning.
*Do.....	1	6	69	51	Do.
Cosmos.....	$\frac{3}{4}$	12	73	92	Do.
Cuphea ignea (cigar plant).....	1	10	69	90	Do.
Cyclamen persicum (in flower).....	$\frac{1}{2}$	13	61	89	Do.
Cyclamen latifolium.....	1	14	69	90	Do.
Cyperus alternifolius (umbrella sedge).....	$\frac{3}{4}$	12	73	92	Do.
Do.....	2	1	68	83	Do.
Delphinium (annual larkspur).....	1	10	69	90	Do.
Dracæna (<i>Cordyline indivisa</i>).....	2	15	71	68	Do.
Dusty miller (<i>Centaurea cineraria</i>).....	1	10	69	90	Do.
Do.....	2	1	68	83	Slight injury.
Elephant's ear (<i>Colocasia esculenta</i>).....	2	1	68	83	No burning.
Evonymus japonicus.....	$\frac{3}{4}$	12	73	92	Do.
Evonymus radicans.....	$\frac{3}{4}$	12	72	92	Do.
Evonymus sieboldiana.....	$\frac{3}{4}$	12	72	92	Do.
Evonymus variegata (radicans).....	$\frac{3}{4}$	12	73	92	Do.
Ferns:					
*Adiantum sp. (maidenhair fern).....	$\frac{3}{4}$	16	69	67	Do.
Do.....	5	13	66	53	Slight injury (old growth).
Cyrtomium falcatum (holly fern).....	$\frac{1}{4}$	14	59	83	No burning.
Cyrtomium rochfordianum.....	$\frac{1}{4}$	14	59	83	Do.
Dryopteris viridescens (glossy wood fern).....	1	14	69	90	Do.
Nephrolepis sp.....	1	14	69	90	Do.
Nephrolepis exaltata bostoniensis (Boston fern).....	$\frac{1}{4}$	14	59	83	Do.
Do.....	1	14	57	-----	Do.
*Nephrolepis furcans.....	$\frac{3}{4}$	16	69	67	Do.
Pteris spp.....	$\frac{1}{4}$	14	59	83	Do.
Ficus elastica.....	1	14	69	90	Do.
Ficus pandurata.....	1	14	69	90	Do.
Forget-me-not (<i>Myosotis</i>).....	$\frac{1}{2}$	12	73	93	Do.
Freesia.....	$\frac{1}{4}$	14	59	83	Do.
Fuchsia.....	$\frac{1}{4}$	10	69	90	Do.
Geraniums:					
Pelargonium sp.....	$1\frac{1}{2}$	14	69	90	Do.
Lady Washington (<i>P. domesticum</i>).....	$\frac{1}{2}$	14	69	90	Do.
Rose (<i>P. graveolens</i>).....	$\frac{1}{2}$	11	63	98+	Do.
Gladiolus.....	$\frac{1}{4}$	1	61	89	Do.
Gloxinia.....	$\frac{1}{2}$	11	63	98+	Severe injury.
Grape, Concord, (<i>Vitis</i>).....	$\frac{3}{4}$	12	73	92	No burning.
Guava (<i>Psidium</i>).....	$\frac{1}{4}$	11	63	98+	Slight injury.
Heliotrope (<i>Heliotropium peruvianum</i>).....	$\frac{1}{2}$	14	69	90	No burning.
Hibiscus cooperi.....	$\frac{1}{2}$	12	70	91	Do.
Hydrangea otakura.....	$\frac{1}{2}$	12	70	91	Do.
Ivy (<i>Hedera helix</i>).....	$\frac{3}{4}$	12	73	92	Do.
Jasminum:					
Grand Duke.....	$\frac{1}{2}$	14	74	61	Do.
*Grandiflorum.....	$\frac{1}{2}$	16	69	59	Tips burned slightly.
*Multiflorum.....	$\frac{1}{2}$	15	63	55	Do.
Nudiflorum.....	$\frac{3}{4}$	12	73	92	Do.
Primulinum.....	$\frac{3}{4}$	12	73	92	No burning.
Jerusalem cherry (<i>Solanum pseudocapsicum</i>).....	$\frac{1}{2}$	11	63	98+	Do.
Justicia rosea.....	$\frac{3}{4}$	12	73	92	Do.
Kerria japonica.....	$\frac{3}{4}$	12	73	92	Do.
Kudzu vine (<i>Pueraria thunbergiana</i>).....	2	1	68	83	Do.
Lavender (<i>Lavendula officinalis</i>).....	$\frac{3}{4}$	12	73	92	Very slight tip burn- ing.
Lantana camara.....	$\frac{1}{2}$	12	73	93	Very severe burning.

TABLE 3.—Results of fumigation with calcium cyanide in greenhouses and fumigation boxes—Continued

Name of plant	Cyanide per 1,000 cubic feet of space	Length of exposure	Green- house temper- ature	Green- house hu- midity	Effect of treatment on plants
	Ounces	Hours	° F.	Per cent	
Lantana camara.....	$\frac{1}{2}$	12	73	93	No burning.
Lantana sp.....	$\frac{1}{2}$	13	61	89	Do.
Lemon verbena (<i>Lippia citriodora</i>).....	$\frac{1}{2}$	14	61	89	Do.
Lilium giganteum (Giant lily).....	$\frac{1}{2}$	14	74	61	Very slight tip burn- ing. ¹
Marguerite daisy (<i>Chrysanthemum frutescens</i>).....	$\frac{1}{4}$	13	63	84	Slight injury.
Do.....	$\frac{1}{4}$	15	65	56	No burning.
Marigold (<i>Calendula officinalis</i>).....	$\frac{1}{4}$	13	61	84	Do.
Moonflower (<i>Ipomœa grandiflora</i>).....	$\frac{1}{2}$	1	72	75	Do.
Moonflower (<i>Ipomœa tubiculata</i>).....	$\frac{1}{2}$	12	73	93	Very severe injury.
Night-blooming cestrum (<i>Cestrum nocturnum</i>).....	2	1	68	83	Slight injury.
Oleander (<i>Nerium oleander</i>).....	$\frac{3}{4}$	12	73	92	No burning.
Orchid:					
<i>Cattleya</i> sp.....	1	14	69	90	Do.
<i>Cypripedium</i> (2 varieties).....	1	14	69	67	Do.
<i>Lælia</i> sp.....	1	14	69	90	Do.
* <i>Oncidium</i>	$\frac{1}{2}$	15	68	42	Do.
Do.....	$\frac{1}{2}$	14	61	49	Slight injury.
Do.....	1	14			Severe injury.
Palms:					
<i>Kentia</i> sp. (Howea).....	1	12	66	85	No burning.
<i>Pandanus veitchi</i>	1	14	69	90	Do.
<i>Peristrophe</i>	$\frac{1}{2}$	12	73	85	Do.
<i>Periwinkle</i> (<i>Vinca</i>).....	$\frac{1}{2}$	14	69	90	Do.
<i>Petunia</i>	1	6	64	91	Slight injury.
<i>Pittosporum</i>	$\frac{1}{2}$	11	63	98+	No burning (older leaves).
<i>Plumbago capensis</i>	$\frac{1}{2}$	11	63	98+	Slight injury.
<i>Pumbago capensis alba</i>	$\frac{1}{2}$	11	63	98+	Do.
<i>Poinsettia</i> (<i>Euphorbia pulcherrima</i>).....	$\frac{3}{4}$	12	73	92	No burning.
<i>Primula obconica</i>	$\frac{1}{4}$	14	59	83	Do.
Rose:					
<i>America</i>	$\frac{1}{2}$	14	63	84	Do.
<i>American Legion</i>	$\frac{1}{4}$	13	63	84	Do.
<i>Butterfly</i>	$\frac{1}{4}$	13	65	80	Do.
<i>Cecile Brunner</i>	$\frac{1}{4}$	15	65	80	Do.
<i>Claudius Pernet</i>	$\frac{1}{4}$	12	72	95	Do.
<i>Columbia</i>	$\frac{1}{4}$	12	66	90	Do.
Do.....	$\frac{1}{4}$	14	57		Sepals burned.
<i>Commonwealth</i>	$\frac{1}{4}$	14	63	84	No burning.
<i>Killarney</i> (double white).....	$\frac{1}{4}$	13	63	79	Do.
Do.....	1	10	69	90	Do.
<i>Premier</i>	$\frac{1}{4}$	9	65	86	Do.
<i>Rosa odorata</i>	$\frac{1}{2}$	12	72	91	Slight injury.
<i>Sanchezia nobilis</i>	$\frac{3}{4}$	12	73	92	No burning.
<i>Sansevieria zeylanica</i>	$\frac{3}{4}$	12	73	92	Do.
<i>Santalum</i> (sandalwood).....	$\frac{1}{2}$	12	70	91	Do.
<i>Scarlet sage</i> (<i>Salvia splendens</i>).....	$\frac{1}{2}$	15	65	80	No burning (1 bloom).
<i>Schizanthus pinnatus</i>	$\frac{1}{4}$	1	61	89	No burning.
<i>Sensitive plant</i> (<i>Mimosa pudica</i>).....	$\frac{1}{4}$	11	63	98+	Severe injury.
<i>Serissa foetida</i>	$\frac{3}{4}$	12	73	92	No burning.
<i>Silk oak</i> (<i>Grevillea robusta</i>).....	2	1	68	83	Do.
<i>Snappdragon</i> (<i>Antirrhinum majus</i>).....	$\frac{1}{4}$	13	61	84	Do.
Do.....	$\frac{1}{4}$	14	59	83	Severe injury. ²
<i>Snappdragon</i> (<i>Antirrhinum</i> sp.).....	$\frac{1}{2}$	14	69	90	No burning.
<i>Spanish iris</i> (<i>Iris xiphium</i>).....	$\frac{1}{2}$	11	63	98+	Do.
<i>Spider lily</i> (<i>Hymenocallis</i>).....	$\frac{1}{2}$	11	63	98+	Do.
<i>Spiræa billiardi</i>	$\frac{3}{4}$	12	73	92	Do.
<i>Spiræa lindleyana</i>	$\frac{1}{2}$	12	70	91	Slight injury.
Do.....	$\frac{3}{4}$	12	73	92	No burning.
<i>Spiræa opulifolia</i>	$\frac{1}{2}$	12	70	91	Do.
<i>Spiræa vanhouttei</i>	$\frac{1}{2}$	12	70	91	Do.
<i>Sultan's balsam</i> (<i>Impatiens sultani</i>).....	$\frac{1}{2}$	12	73	93	Do.
Do.....	$\frac{1}{2}$	12	73	85	Slight burning.
<i>Sweet olive</i> (<i>Olea fragrans</i>).....	$\frac{3}{4}$	12	73	92	No burning.
<i>Sweet pea</i> (<i>Lathyrus odoratus</i>).....	$\frac{1}{4}$	13	54	76	Do.
Do.....	1	12	62	93	Slight injury.
<i>Tapioca</i>	$\frac{3}{4}$	12	73	92	No burning.
<i>Thistle</i> (<i>Onopordon</i>).....	$\frac{3}{4}$	12	73	92	Do.
* <i>Wandering Jew</i> (<i>Tradescantia</i>).....	$\frac{1}{2}$	15	72	49	Do.
<i>Wax mallow</i> (<i>Malvaviscus arboreus</i>).....	$\frac{1}{2}$	12	70	91	Do.
Do.....	$\frac{3}{4}$	12	73	92	Do.
<i>Weeping willow</i> (<i>Salix babylonica</i>).....	$\frac{1}{2}$	12	70	91	Do.

¹ In flower.² Leaves spotted, flower sepals bleached.

